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BULLETIN
OF THE SOCIETY OF ARTS

MARCH 1909

LECTURES IN MARCH AND APRIL

All Interested are Welcome

659th Meeting
March 15th

Mr. Howard W. DuBois, Mining Engineer of Philadelphia, will speak in Huntington Hall on March 15th, at 8 p. m. His topic will be "The Determination of Salting in Mine Examinations." He will treat this from a more or less popular side, showing a few artistically colored lantern slides of bearing on the subject. The slides alone will be of enough interest to warrant your coming to the lecture.

660th Meeting
March 25th

Dr. Robert S. Woodward, President of the Carnegie Institution of Washington, D. C., will speak in Huntington Hall on "The Larger Research Problems of the Carnegie Institution," March 25th at 8 p. m. The Carnegie Institution is doing a great work along research lines, about which the public in general knows comparatively little. Dr. Woodward will throw much light on this interesting work.

661st Meeting
April 5th

Prof. Geo. E. Hale, Director of the Carnegie Solar Observatory at Mount Wilson, Pasadena, Cal., will address the Society on "Solar Cyclones and Magnetic Fields." The address will be in Huntington Hall at 8 p. m. This will be the last regular meeting of the Society for the present season.

THE SOCIETY OF ARTS OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY

The Society of Arts was established as a department of the Institute by President Rogers in 1861.

It is especially devoted to the general dissemination of scientific knowledge and it aims to awaken and maintain an interest in the recent advances and practical applications of the sciences.

Any person interested in the aims of the Society is eligible to membership.

The annual dues are $3.

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THE DETECTION OF SALTING IN MINE EXAMINATIONS

By Howard W. DuBois, Mining Engineer, Philadelphia

The term "salting," as used by mining engineers and those accustomed to invest in mining properties, refers in a broad way to all sorts of deceptions that may be practiced upon the prospective purchaser, either of mining property or mining securities, for the purpose of making him think that the property is more valuable than it really is.

The examining engineer is at a great disadvantage from strange surroundings at a mining property, where sometimes everyone considers it to his general interest to assist in unfair practices, and to deceive the expert as much as possible. The books of a mine are often fixed up to show good returns in corroboration of apparently valuable assays, whereas the operations have actually been carried on at a loss, and there are cases on record where gold has been purchased for large sums for the purpose of salting the ore as it goes through the smelter, thus making apparently a very creditable showing at the mine. Such evidence as this, if accompanied by apparently favorable assays of samples actually taken, would materially assist in misleading the mining engineer to think that his samples were fairly representative.

Salting may be done in either of several ways to advantage. It may take place in the mine itself previous to examination. This method involves considerable expense, and in the case of a low-grade mine is rather difficult to carry out successfully. Precious metal mines are mostly selected for the salters' art, but cases have been known where attempts have been made to salt an iron mine, which ought, however, to be a very difficult thing to do successfully upon a competent engineer. Thousands of dollars worth of genuine diamonds have been thrown carelessly over large areas to give the appearance of rich diamond fields, and thousands of dollars worth of valuable ore has been placed in the ore piles to be examined, and expert engineers have been deceived. Generally a mine, if a large one, cannot be salted all over; hence, the advantage of taking a large number of small samples from as many different parts of the mine as possible, rather than a small number of large samples.

The cheaper method is to salt the engineers' samples, and besides a better control can be obtained as to the strength of salting; thus less suspicious values are likely to be obtained on assay. In cases where engineers have had their samples salted, the facts are not likely to leak out, owing to the personal element that enters into such matters. No one cares to make a public record of the fact that he has been a victim of such an experience.

No absolutely sure method has ever been devised as a protection against salting. It requires the greatest vigilance on the part of the engineer to make reasonably sure that the mine has not been salted at any one of the many opportunities that present themselves in the course of the examination. Bags containing samples should be sealed with lead seals instead of the ordinary sealing wax, which are too readily duplicated. It is absolutely necessary that these bags should not be out of sight of the engineer or his assistant. Final samples should be placed in a strong trunk, and the greatest care taken that there is no opportunity of tampering with them. In order to have some check as to whether one's samples are being salted or not, it is a good practice to introduce sample bags filled with ore of known assay value and place them in tempting situations.

Despite many cases of the attempted salting of mines, in all justice to the mining business, it is fair to state that probably the majority of mining properties are honestly developed for purchase, but it is not well for the mining engineer to assume this, as otherwise he might be too readily caught.

Mr. DuBois is an engineer of wide experience in mine examinations, and comes from Philadelphia expressly to tell our members and their friends about this important and serious problem in connection with the practical end of mining investments.

A few artistically colored lantern slides will be shown, having a bearing on the subject.

THE WORK OF THE CARNEGIE INSTITUTION OF WASHINGTON

Dr. Robert S. Woodward, President of the Carnegie Institution, at the meeting of the Society of Arts on March 25th, will describe the foundation of the Institution by Andrew Carnegie, its organization and purposes, and the various lines of investigation which are being pursued under its direction. These include researches in widely varied fields of pure and applied science—in economics and sociology, history and archæology, experimental evolution, marine biology, plant life, nutrition, geophysics, terrestrial magnetism, meridian astronomy and solar physics. Among the problems which have attracted much popular interest may be mentioned the studies of Luther Burbank in producing new and valuable varieties of fruit, and the investigations of the desert laboratory in studying the forms of vegetation best adapted to arid regions.

SOLAR CYCLONES AND MAGNETIC FIELDS

On April 5th Professor George E. Hale, Director of the Carnegie Solar Observatory at Mount Wilson, California, will address the Society on " Solar Cyclones and Magnetic Fields." This observatory, supported by the resources of the Carnegie Institution, has been equipped with instruments of extraordinary power and efficiency, including a five-foot reflecting telescope, a vertical tower telescope of great focal length giving a very large image of the sun, and spectroscopes of the highest dispersive power. With the aid of these instruments and of the unusually favorable atmospheric conditions prevailing on Mount Wilson, Professor Hale and his staff have been able to make observations on the solar phenomena which have thrown much light on the nature of sun spots and on their relation to magnetic disturbances upon the earth. The sun is being studied primarily as a typical star; and the results obtained constitute a contribution to the fundamental question of cosmic evolution, the study of which forms the main problem of the Carnegie Observatory.

The 657th meeting of the Society was held in Huntington Hall on February 11, 1909, in commemoration of Darwin's anniversary, about 650 persons being present. Dr. A. A. Noyes presided; two speakers were heard. Professor Sedgwick, of the Institute of Technology, spoke of the Organic Evolution, and Professor Lowell spoke most fittingly of the inorganic. His address follows:—

INORGANIC EVOLUTION

A great man never dies; he lives forever in the thoughts he has begot. It is his birth that we remember, and to commemorate its centenary that we are gathered here to-night. From my eminent colleague you have heard the well-told story of Darwin's life; to me has fallen the co-honor of considering the general principle for which that life stands famous. Although the Origin of Species is Darwin's monument, while it is primarily the Genesis of Worlds of which I am to speak, to part them were paradoxical since the ultimate outcome of evolution is the oneness of the two. The organic, in fact, is but the latest chapter of a serial which has been running through the ages. It is the culmination to date of a long preparatory career. Though for us, not the least important part of it, in duration it has been brief compared with the aeons during which the prefatory process stretches back into the past.

Evolution is nothing more nor less than the mainspring of the universe. Grand in its very simplicity it is the one fundamental fact to which all we know is ancillary. From its influence nothing can escape; for it has fashioned everything from nebula to man. Without it the cosmos would be a chaos which never changed. A trifling scholium from its axiomatic force is that without it you and I would not be here to-day.

Considering the simplicity, the universality, the importance of it, the surprising thing is that it should have escaped most men's recognition so long. For we find it through the ages realized only by the master minds. Considering that man stands confronted by instances of it from his cradle to his grave, one is tempted to believe that the sole object exempt from its working, the one thing incapable of growth, is the mind of man himself. Certainly his self-bestowed title of *homo sapiens* can be only by brevet, a hoped-for honor to which the race has not yet attained. Quickness of apprehension is not his distinguishing trait. Yet considered from the standpoint of evolution, the situation is perhaps all one could expect.

Pushed or prompted from the forest, primeval man stood ushered on the plains. With the opening of the prospect thus laid before him began the widening of the horizon of his mind. Through this as much as through anything he parted company from the brutes. Search for subsistence led him to wander, and his wanderings lured his mind to journeys farther still. Alone with his flocks on the wide Chaldean steppes, his thoughts perforce gravitated to the stars. Something beyond the earth began to exist for him as he sat and watched them revolve silently overhead. Not less was communion with them established through his voyages by sea. They must already have been known when boldly the Phœnicians pushed out into the broad expanse of the Mediterranean, to be guided by the sun by day, by the constellations by night. Homer tells us what stars they steered by, and it argues no mean familiarity with the heavens that they dared to be thus piloted, no matter what the season of the year. So much of knowledge led to more. We may even trace its source. Mnesarchus, the father of Pythagoras, is said to have been a Tyrian merchant, who settled finally in Samos, and it was doubtless from sailing with him through the long, cold winter nights, steering by the stars out of sight of land, that the boy's thoughts were turned to thinking what they meant—to better purpose than is commonly supposed. For the higher minds among the ancient Greeks reached marvelously correct ideas of the structure of the universe, considering their instrumental limitations. Pythagoras, five centuries and more before Christ, was perfectly aware that the earth turned on her axis and revolved about the sun; and his doctrines, written out and extended by his follower Philolaus, were handed down in secret for fear of priestcraft through the centuries that followed. Debased on purpose for exposition to the people, the memory of the truth was lôst, and so it came about that that arch-mediocrity, Ptolemy, imposed upon the world, to dominate it for more than a millenium, a false earth-centred astronomy by means of an imposing book.

The idea of evolution, too, had entered the keen Greek mind. Anaximander (611 to 545 B. C.) taught that out of a vast and limitless body there grew a central mass, our earth, and out of the earth came life. Man, himself, he supposed had sprung from other animals, probably marine. Anaxagoras (450 B. C.) also conceived a cosmogony in which motion was the ruling spirit, and minute particles of things were segregated to their present state. Cold played a part in this, and animals evolved in the earth's aboriginal moist clay. In Empedocles' scheme we find spontaneous variation and the eventual survival of the fittest. While Lucretius in his great poem on the Nature of Things, in which he resumed the learning of his foretime on the subject, says appositely (Book V, 826–7) that the earth herself brought forth life, and ceased only because she, too, passed the bearing age. Thus did the ancients strangely adumbrate the truth. Their cosmologic building differed from that of later ages chiefly in the character of the bricks. For the physical laws on which all such structures must be founded had not yet been learnt.

Then came the long night of the Middle Ages when thought itself was blotted out. Nor did the idea of evolution come in with the dawn again of learning. Intellectually men began anew, and took things as ready-made as a child his toys. Even the discoverer of the law of gravitation saw interposition in the orderly arrangement of the planets, from which the comets had been left exempt, and foresaw further interposition necessary to keep them going in the future. He tells us so very explicitly in his general scholium at the end of the *Principia*.

It was not till the middle of the seventeenth century of our era that the idea that the universe has evolved seems again to have occurred to man.

Descartes (1744) led speculation with his theory of vortices, the sun and planets being due to swirls in a continuous matter pervading space. It was accepted for twenty years or more by the best minds of the day: Liebnitz, Huygens and the like, to be finally demolished by Newton. A century later Kant devised another origin for the solar system. It might have been superb had Kant's knowledge of physics equalled his divining sight. He conceived a primal nebula originally at rest, to have given birth to the sun and his cortege by the falling together of its parts, a self-acquired vitality of movement we now know to be as impossible as the lifting oneself by one's bootstraps. To be commended for its daring, though, this bold modern driving of the chariot of the sun!

To Laplace, a generation later, is due the first truly scientific attempt at explanation. For it is one thing to perceive that the solar system must have grown to its present state, as a boy grows, by a development intrinsic to itself and another to point out the actual steps of the process. Laplace in 1796 in his Exposition of the System of the Universe, advanced a cosmogony with the reserve of a great mathematician who realized that observation and calculation alone can give certainty of result, which dominated scientific thinkers for three quarters of a century. At the time it was published it seemed to account for the then known facts.

Laplace supposed a primal nebula tenuously vast, which rotated as a whole because of friction between its parts. Contracting under its own gravity it spun faster as it condensed till its outer parts attained such speed they reached the limit of abandonment, and a ring was left behind. Contracting further another ring was ultimately detached, and so the process went on, each ring in due order of distance from the sun.

These gathered upon themselves to form the planets which, still contracting and twirling faster as they shrunk, threw off their satellites in turn. A grand conception for its simplicity, but too simple to be true. The advance of science since has disclosed some fatal flaws in it which have obliged its giving up. First: the necessary friction for such solidarity of movement is not in nature. Substitutes for this have since then been devised, but unavailingly to save the Laplacian idea, for other flaws in it are irremediable. The solar system is not as uniform in plan as then was thought. Especially must the comets be accounted for. Laplace expressly excepted them for he considered he had proved them unattached visitors from other stars. Two errors cause him thus to think: one a mathematical mistake first pointed out by Gauss, the other the overlooking of the sun's motion through space. He believed he had shown that the orbits of the comets were such as should mathematically be expected did those bodies come to us from without. But in the course of his analytic transformations he had taken as convergent a series which in reality was not, and his formulæ had been vitiated in consequence. Gauss detected and exposed the error; then later Schiaparelli wrote a paper showing on the other lines that the comets must be deemed our own; and lastly Febry, of Marseilles, in a masterly memoir not sufficiently known, has demonstrated that were the comets not members of our solar system, hyperbolic, or unclosed, orbits among them should be very common, not one of which for certain has ever been observed.

That the precise manner of the cosmos' growth escaped its first investigator is not strange, as it has more or less eluded every thinker since who has tried to portray it. Yet by standing on the shoulders of those who went before each generation has seen a little farther than the last. New acquisitions in physics though disproving hypotheses once held have led us by so much nearer to the truth. Its history is the chronicle of a most brilliant march of the human mind which had been more than human, had it not been cumbered by mistake. To miss the road at times does not preclude an eventual reaching of the goal. For science is not a chain of disconnected, successively discarded beliefs, as is sometimes popularly supposed, but itself a development growing to greater generality and so to truth as its horizon widens. It is itself the architype of what it seeks to interpret.

More has now to be explained than Laplace contemplated. Thus comets, now known to be part and parcel of the solar system and not vagrants from interstellar space, demand recognition in any evolutionary scheme. Other autochthonous intruders too, undiscovered a century ago, disturb the harmony of the Laplacian plan. Unconforming members, these, that cannot be ignored. It is in its outer parts that the system shows thus different and complex. The distant planets do not rotate in like sense with the near while their satellites all retrograde. Then, too, the new-found satellite of Saturn and that of Jupiter too move contrarywise from what their sisters do. Significant it is that it should always be the peripheral parts of the system that differ from the main. Kirkwood, Roche, Trowbridge, Faye, Ligondes and others have met these difficulties singly or *en bloc* by explanations more correct than compelling. For in so many-elemented a matter the might be is other than the must. One *vera causa* has certainly been acquired, not subversive of, but supplementary to, what went before. For a previously unreckoned factor is tidal evolution. We owe its recognition to one almost unknown while he was living, the brilliant Edouard Roche. Ancillary, not all-directing, it has helped shape the system to its present state. At the hands of Sir George Darwin, the eldest son of the great naturalist, it has been made to account for the birth of the moon; and at those of See for the genesis of double stars. Certain it is that the system bears evidence of this action in the countenance it presents. Just as the moon shows us always the same face, so Mercury and Venus we now know turn in perpetuity to the sun, and the best seen satellites of the other planets do the like. Tidal friction this bespeaks. To this cause, too, may the planet's axial tilts progressing from inversion to uprightness as one comes inward to the sun, in all probability be ascribed, as Kirkwood first pointed out (1864). Strange to say perhaps the latest news about our solar family has come from the smallest and most seemingly insignificant of its members. It is just because they are the simplest of its constituents and the least developed that they bear witness so well. Ask the children of a household, not their elders, for domestic facts. These little telltales are the meteorites, the stones which fall from heaven from time to time. Shrewdly questioned these bits of meteoric stone and iron have a most surprising story to unfold, a tale which stretches so far back into the past as to stagger thought, and yet so fresh in their embalming of it as to seem of yesterday. Their speeds and their great numbers show that they are cosmic bodies like the planets themselves, the unswept up remnants in fact of what once strewed space and out of which the planets were formed. They are thus parts of the primal nebula. But important as this is, it is not all. Through the strange fretwork of their face, like the frosting of the cold of space upon the windowpane of time, we gaze upon a state of things antedating that nebula itself. For their Widmanstattian figures betray a constitution different from any known on earth.

Most nearly kin to our deep minerals, their character and speed proclaim them as once part of some great solid globe placed where our sun now is which at one time had itself been hot and subsequently had cooled. Fragments now, scattered orphanwise in space, they speak mutely of their parentage and of the mighty cataclysm in that body whose shattering gave them birth. Parts of what went before, parts too of what is to-day, they are themselves the link in our chain of evidence connecting the present with the past, proving how we came to be. They are the tangible realization of what the philosophic seers saw with the mind's eye down the far vista of recalled time. Had anyone told Laplace that man would ever hold and handle parts of the very nebula from which we sprang surely no one would have been more surprised than he.

From the information afforded us by meteorites we turn to another discovery of recent date, the recognition of the spiral nebulae. So-called, for their striking structure, they are also known as *white* for their spectroscopic look. Known for long in some few instances it is their overwhelming commonness which has lately been described. For they prove to constitute by far the greater number of all the nebulae in the sky and are sharply differentiated from the other class, the irregular or *green* ones. To them there is reason to believe all intermediate forms belong; the ring nebulae being in reality spiral and the planetary nebulae, types perhaps of the same process reduced to its lowest terms. Their structure speaks unmistakably of evolution, and their universality proclaims such evolution to be the inevitable procedure of the universe.

Their color, white, arises from their showing a continuous spectrum, and indicates that they are composed in large part at least of solid particles, whereas the *green* tint of the others comes solely from glowing gas. Now this spectrum is just what they should show were they flocks of meteorites—and such undoubtedly they are. They give us, therefore, the second chapter of the evolutionary history. For from their peculiar structure we are able to infer what the process was that scattered the constituents of the once compact ball whose existence the meteorites attest. They consist of a central core from which two spiral coils unfold, the origin of the one diametrically opposite the other. Now this is what would happen had the original mass been tidally disrupted by a passing tramp. Tides in its body would be raised toward and opposite the stranger, and these would scatter its parts outward; the motion due the tramp combining with the body's spin to produce the spiral coils we see. Just as in the meteorites we have found the substances from which our solar system rose; so in these nebulae we see an evolution actually in process which may have been our own.

Immense advances, both these facts, to our certainty of the subject, though the details of the method still elude our search.

But the nebular hypotheses of mechanics are only the outer portals and broad avenues of evolution. They leave us on the threshold of where the greatest, because the most intrinsic, interest begins; that strange development by which the inorganic grew into the organic by due process of change. To Lockyer we owe its far-off preface-reading in the chemistry of the stars. The dissociation of matter he thought to mark in the hottest of these suns is the point at least from which evolution set out. His detailing of the process has not indeed proved true, but his detection of where and how to look for it is not by that impaired. Just as the real nebula was not as Laplace supposed, so with Lockyer's dissociation of elements in the stars. Matter may not be resolvable in the manner that he thought, but that evolution is the inevitable concomitant of the process of cooling down, everything testifies to be the fact.

Coming earthward from the stars we can mark this causal cooling through the whole range of evolutionary development. One stage of it we see in the present constitution of the sun; another in its retinue of worlds. In our great hearth-fire all substances are in their elemental state. It is too hot there for chemical affinity to act. In the major planets where the heat is less, compounds have begun to form, but compounds of which we have no counterpart on earth. We note them by their unknown spectral bands, so beautifully brought out by Slipher, and we know they must be compounds as we do not find them in the stars. In our own world where it is colder still, chemical combination has advanced yet further, and has been doing so increasingly since the earth began to cool. In the record of the rocks we read of eras when only the organic could exist. Then, as that same history reveals, the greater intricacy of the organic molecule became possible through the tempering of its habitat. The step was taken which seems to us so great but was in fact so small, the waking of the molecule to life. That its beginnings cannot be reproduced in laboratories to-day is because the conditions that evolved them have themselves changed and those conditions are well-nigh impossible to record. In Lucretius' words our mother is too old. Nevertheless, as Professor Jaggar has suggested, volcanoes, hot springs and their surroundings, the dying out conditions of the primeval world, are the place to look for such instructive atavism to-day; and there possibly a clue to it may yet be found. Meanwhile noteworthy experiments by Burke with radium on gelatinous films in sterilized tubes have led to growths singularly simulative, to say the least, of the reality; while still other very remarkable ones by Bose upon the responsiveness of metals, plants and animals, go in another way to demonstrate them kin.

Just as researches on this earth all point to the bringing forth of life by a planet as the necessary outcome of its own career provided its physical condition be right, so has investigation in the sky. From our island home in space we may peer across to other islands voyaging through the void and by telescopic help mark what there is going on. In very different stages we find them, of their own evolutionary career. Such diversity of itself attests a general development, for on no two were either the beginnings or the course the same. Some are youthful, some are old; some fairly like us at the start, some fundamentally diverse. Only where conditions are roughly similar could we expect to behold anything familiar and even there it would not be the same. All the more compelling if we find evidence of the oneness of the whole. Now within the last few years research has brought to light testimony that our nearest of solar kin has had its organic history too. Upon the planet most likely to support such existence at the present moment, other than ourselves, study has disclosed features which cannot be explained except as evidence of transplanetary life. Pregnant with thought this is, for it brings corroboration of the whole evolutionary process from beyond the confines of our native earth. That the inorganic should develop into the organic on a single planet might perhaps be accidental but not on two. From Mars comes the cosmic assurance that it is true.

When now in retrospect we contemplate this growing recognition of the universe's march two thoughts come to us together: one of admiration, the other of surprise. For a certain grandeur possesses us at the thought of man's perception stretching out into the vastness of space and by it being carried into the immensity of time. Man! whose little life is rounded out by three score years and ten and whose tenantable domain is the film-like cuticle of this small earth: an inheritance shrinking like Balzac's Peau de Chagrin year by year through its enjoyment by mankind, who exterminates its simpler denizens, deforests it of trees, and crowds it continuously more and more. That man whose ancestors entered on all fours, should at last look up: then look before, and after and ultimately beyond, has in it force to fire imagination and clothe him with something close of kin to immortality.

Side by side with this is the wonder that it took so long. How man, so ingenious in what affects him, should have been blind to the process of which he is a part, seems glaringly absurd. One had almost deemed the thought intuitive, did man not insist on testifying to the reverse. To-day's protagonist makes this singularly clear. Darwin's contemporaries refused even to consider his conception, demanding proof he had not to give. Conclusive evidence they wanted, deaf to the self-conviction of common sense. Theirs was the praiseworthy logic of the Irishman who, when arraigned on a charge of theft, and asked if he plead guilty, answered, "Faith, and how can I tell until I've heard the ividence." Logic is good, but the analogic at times does better. For there is nothing but what by slow gradation is turning into something else. The very world he lives in changes while he is there, and the earth he waked to as a boy, by middle age has already passed away.

His very opportunity for noting was cause why he failed to see. What is oft repeated ceases to impress. Familiarity dulls perception and leads us to accept as matters of course the daily miracle of the course of matter. His unique position as the highest product of that evolution up to date abetted his blindness. He was too self-centered to look around. The interest of self that nature gave him to further and perpetuate his kind grew by what it fed on till in its overweening vanity it shut out all beyond. From the moment he began to think we find him fashioning the universe about himself as core. His very fears and weaknesses receive anthropomorphic treatment at his hands and hover round him to injure if not propitiated or cajoled.

All else he finds designed to minister to his wants. The spot he stands on must be the pivot about which the very cosmos turns. The earth, forsooth, is the center of the universe because to have it otherwise detracts from his importance and minifies his fame. Around it must turn the sun and about it revolve the stars. And all because nature implanted in him the sense of his own importance that he might the more evolve. Puppet of her contrivance he has outdone her most sanguine hopes by taking seriously the flattery she meant as spur. The humoring of nature has its innate humor too.

Out of this plane of myopic mediocrity arises now and then a man. A mutation, the biologist would call him a sport. And the world's sport he usually is or worse. He differs from his fellows and the fact that he does so differ is cause for condemnation at once. All animals do the like. It is a well-known biologic law. Only his intrinsic excellence enables him to survive; the fact that he can stand alone. The sole difference in the case of man is that in man the variation is mental, bodily with brutes.

Now the chief distinction between this man and his mates is one which you might not at first detect. For it is the same by which they differ from him. It is that he is intrinsically distinct. Not so much that his intellect is keener, nor that his energy is great, though both these are ancillary to the result, but that he sees things untrammeled by the prejudices of his time. He rises superior to the crystallized conceptions of the race. This may seem to you a trifling matter, in truth it resumes all. If you scan history you will find that every age has had its dogmas in every branch of life, dogmas which have completely swayed the thought of its day. It is part and parcel of man's constitution that this should be so. Without the balance-wheel of conservatism the human machine could hardly run. Nor were such ideas blamable at the time they first took start. But it is no exaggeration to say that not one of them but had become a debased fetish at the time of its greatest cult. Like coins that long pass current the face they stood for has been worn off, though their face-value remain the same. The world that uses them as counters is a different world from that which gave them vogue.

The quality of a genius consists in the ability to put off these shackles to reason and see things as they are.

Bowing neither to custom nor authority he perceives facts undistorted by the glasses society has self-imposed. Perspective orders thus the view ; and imagination synthesises the survey to inevitable conflict with his time. Lamarck saw thus and Darwin, too ; and both in their day were the abjured not only of the ignorant but of that lower class of scientists who conceive science to be limited to the accumulation of facts. The fact-gatherer is a necessary factor to all advance, but for him to usurp its captaincy is like the labor champion who claimed that labor built the railroads because it laid the rails. "Did you ever think," said the man he addressed, "that the end attained depended on where the rails were laid?"

By rising above the conventionalities and prejudices of his time the genius attacks the problem with an open mind and gives his own fertility free scope. Had the old Greeks not been ingrained with the notion that the circle was the only perfect figure, and thus the only one the heavenly bodies could pursue, they might themselves have discovered the elliptic character of the planet's paths. Kepler by discarding the dogma lit upon the law. So Darwin upset old tradition by looking it in the face. The eventual effect of such envisaging is twofold ; direct upon those capable of comprehending it, indirect in changing the mental attitude of mankind at large. And the second is the more potent of the two. The chief function of genius is to change the world's point of view.

The point of view has more to do with comprehension than any amount of proof. You all remember how Voltaire exposed the social fallacies of his time by introducing to their notice an unconventionalized soul Candide, and narrating what befell him under the simple guidance of rationality and truth. You know how ill reason fared by the process, though everyone professed to be governed by it. We all now see with Voltaire and are amused at the self-deception of two centuries ago. Yet the mass of us are just as blind when it comes to matters of to-day ; the objects have changed, the subject remains as before. That it was Voltaire also, who introduced Newton to France which before that would have none of him, is worth more than a passing thought.

The fact is we believe we act from reason when reasoning shows that we acted from belief. What we were taught in our earliest years is very hard to unlearn afterwards.

And this is not only natural but the expression of a fundamental cosmic law. You know one quality of matter is what is called its inertia. Inertia means a body's objection to change of state; if the body was at rest, at rest it stays if unimpressed; if moving, it continues to move in the same direction and with like speed. It would go on forever in the same way were no other force or friction to stop it. Now ideas are just as subject to this basic principle as is a common ball. They require force to start them but once started their momentum is immense. They go rolling down the ages long after the force that impelled them has been forgotten, so long since it was spent.

Each century starts with the ideas that it has been bequeathed. To alter them is no easy matter. For whether right or wrong their own momentum carries them on. Even the sun could not stop the earth in a moment. A new idea means the introduction of a new force. Now no finite force can produce its full effect at first. Time is necessary for it to tell even were it to act unhindered. But it is rarely suffered to do anything of the sort. The ideas already in the field oppose to the utmost of their power with the dogged persistency of the popular precept: "Don't push, just shove." No wonder the newcomer finds it hard. When at last such a one has made its way we say: How simple: forgetting that the half of genius is the ability to see clearly where others are preconceivably blind, the other half the force to set its concept going. The more fundamental the idea the more it runs counter to current belief and the harder for it to make headway.

Neither strength or courage is needed to profess what everyone admits; to progress needs both, opposed as it is not only by the ignorant but by the organized scientific orthodoxy of its time. For scientists like other men, are prone to forget that the unaccepted of to-day is the established of to-morrow, and in their attitude toward new concepts remind one of the bashful young man who was afraid to propose. At last his father twitted him with his timidity. "That I should have a son who dared not come to the point. Where would you have been I should like to know had I not proposed to your mother?" "Oh, that is quite different," the son replied, "you only asked mother. I have got to ask a strange girl." Our scientific heirlooms are our mothers; our own additions to science the girl we have got to win. Every mother was a stranger once—and the less near of kin the fresher blood she brought.

Especially is this the case where the new idea affects man's vanity by lessening his self-esteem. Darwin's ideas did both, and many of us can remember the storm of opposition they evoked. Not very creditable, as we look back upon it, to man's intelligence, but understandable when we consider the underlying principle of inertia of mind. Perhaps no event ever brought it out more saliently, crowded with such cases as history is. For common sense rather than uncommon subtlety was here concerned. Proof, properly speaking, there was not. Yet the subversion was complete. Hardly a man of his own generation accepted his ideas; not a man of the next but subscribed.

But there is, unfortunately, a sad side to it which we shall do well to let sink into our hearts. A genius speaks to one world, only to be heard by another. The world of his own day turns a deaf ear to him, the world of the generation that comes after acclaims. The cause is none the less pitiful for being tautologic. Were he not ahead of his time he were no prophet. For a man to get the world's ear while he is yet alive is his damning with faint praise. To be easily appreciated argues one too much a creature of the moment to outlast it long. *Vox posteritatis, vox veritatis.*

But think what this means to the man himself. Imagine yourself alone at night upon some isolated mountain top held up uncurtained to the stars. If you have ever stood thus solitary with nature you will know the awe and loneliness that penetrates your soul. At your feet is rock in naked inhospitality to life; above you is the boundless void, immeasurably far in which shine the frosty stars amid the outer cold of space. Around you are forces with which you have no kin, forces working out their own elemental ends with absolute indifference whether you survive or perish, an indifference that kills. To oppose them all you have but your own unconquerable will.

To be a pioneer in thought is to stand thus alone with nature, not for a few minutes but for life. The isolateness of the few great minds of each generation of men is utterly undreamed of, for want of understanding, by those about them. Yet think what it is to pass one's days in a thought world where the thinker roams alone. To grapple with problems the very terms of which are beyond ordinary comprehension and the solution appreciated only in years to come. To contemplate in lonely ecstacy, after still lonelier despair, the revelation that comes with months and more of pondering. When some one asked Newton how he came to make his wonderful discoveries he replied: "Simply by always thinking about them." Consider Kepler toiling year after year fruitlessly for some ratio that should link the planet's motions by a general law, calculating assiduously and putting hypothesis after hypothesis aside as he found it would not work, until at last, after almost inconceivable toil, he hit upon the one that would.

As if this loneliness by nature were not enough, it must needs be accentuated by man. For he rises in such cases in chorus to condemn. Consider Darwin, in patient study, testing the working out of natural selection and adding fact to fact only to have the whole denounced as ridiculously absurd. Think you the denunciations of the master while living are wholly compensated by the plaudits after he is dead? The loneliness of greatness is the price men make the genius pay for posthumous renown.

To him we may never make amends. But we may vicariously atone for past stupidity by timely care not to commit the like ourselves. The truest tribute to the dead is not to praise him but to practice the principle for which his life was great. Let us, then, free ourselves as much as may be from those blinding prejudices by which each generation seeks to fetter its successor. Let us be open-minded, and remember that the true advance is not to accept to-day what yesterday failed to appreciate, but to champion the advance that now is making while yet it is to-day.

The 658th meeting of the Society was in Huntington Hall on February 27, 1909. Dr. Noyes called the meeting to order at 8 P. M., and presented the names of three persons who had been favorably recommended for membership. After the election of these members Dr. Chas. E. Lucke, of Columbia University, was introduced, and he gave a most instructive talk on Gas Power, the greater portion of which follows:—

THE FUNDAMENTAL PHYSICAL PROCESS BY MEANS OF WHICH POWER IS GENERATED IN INTERNAL COMBUSTION ENGINES

At no time in the history of this country has there been so keen and so general an appreciation of the importance of conserving our natural resources, among the greatest of which, in point of value and universal use, is our fuel supply. Any movement that has for its object the saving of fuel without loss of useful effect should receive the support of every good citizen. One of the greatest drafts on our coal beds is made for power service, so that any effort toward better fuel economy in power generation will result in a very material extension of the time our available supply may be expected to last. It is because the gas power plant has demonstrated beyond question its inherent ability to do the same work with less fuel than is possible with steam plants that it must be placed among the beneficent inventions. By this system of power generation not only can the power fuel supply of the country be made to go from 1½ to 6 times as far as at present, but poor qualities of lignites and peat, now practically useless, will be made available for power purposes. The apparatus by means of which such enormously important results are being worked out operates on principles not at all complicated in themselves often so intermingled as to be difficult of recognition. My belief that some knowledge of the simpler and more basic of these principles would be of interest to every educated person has led me to attempt a discussion of this somewhat technical subject before a semi-technical audience.

In the operation of the factories of this country at the time of the last census, 1900, there was required about eleven and one third million horsepower, of which, roughly, 77 per cent was steam, 15 per cent water power and less than 2 per cent gas power. The average size of each engine was only about 67 H.P. Taking into account in addition to factories the power plants of street railways and public service central stations, as well as all power used in mining and quarrying industries, there was reported about seventeen million (17,000,000), of which fourteen million (14,000,000) was steam, the average size of each unit being quite small in comparison with the maximum. If the average coal consumption per hour per H.P. for the steam plants were placed at the small figure of 3 lbs., the best being 1½ lbs. and a common high value 5 lbs., then the coal consumption per hour for the 14,000,000 steam H.P. of the above industries would involve the consumption of 42,000,000 lbs. or 2,100 tons of coal per hour. The actual hourly consumption of coal for these engines is considerably less than this, because all these units will not be at work all the time, nor will they operate at maximum power even when in operation, and the uncertainty of these factors makes it quite difficult to arrive at a figure of the actual rate of consumption of power coal. Of the amount burned, however, for steam power the gas power plant can save a very considerable sum, the saving depending on the size of units, the nature of the work they are doing, the kind of coal they are burning and a variety of other things.

There is often heard the claim that the substitution of gas power for steam should be made at once because it would result in the doing of 2½ times as much work, or that at the present rate of consumption gas power plants could make our power coal supply last 2½ times as long. Such sweeping statements are based on incomplete comprehension of the conditions and facts, and could be made only by thoughtless enthusiasts. While the steam plant coal consumption per hour per H.P. ranges from 1½ pounds in large, highly refined to perhaps 5 pounds in smaller and simpler steam plants, the corresponding values for gas plants will range from a little over one to a little less than two pounds, so that the saving of the gas plant over coal would depend on the size and types of each used in the comparison. The average size of plant in the above named industries is small enough, being between 100 H.P. and 200 H.P., and of such type as to warrant an estimate of a twofold coal saving provided substitution could be made, which cannot be done as yet because in the first place the bulk of the coal used is of such kind as the gas power plant has not yet been adapted to use, and secondly because the gas plant has not yet been adapted to the service in all cases, and thirdly there are certain financial reasons why the substitution is not warranted. Although it is true that the gas power plant has not yet developed far enough to invade all the fields occupied by these steam plants, yet it is sufficiently perfected and adapted to some of them and the available fuels in the particular locality to warrant immediate substitution, and in proportion as it is substituted and in proportion, at the same time, as it becomes adapted to more and more different varieties of fuel so will it be capable of saving more and more of our enormous coal consumption for power purposes. There is no doubt, therefore, that it is at present a great factor in coal conservation, and will become more and more potent as necessity for conservation becomes more acute.

The substitution of gas power for steam power, no matter what the fuel may be, is not going to be brought about by any principles of philanthropy. It would be folly to suppose that any factory manager would change his steam plant into a gas power plant just because he was anxious to save the national coal supply, nor is it likely the coal companies, who earn in proportion to sales, can be expected to help much. Any manager who made such a change for such a reason would be unfit for his position, unless as a consequence of that change he could show an improvement in his expense account or an increased profit to his particular employer. It is mainly, therefore, on the cost basis that the motive for the saving of our fuel supply by such means as the gas power plant offers, must originate. That a saving in coal does not necessarily involve a reduction of the cost of power is a well-known proposition to power engineers but it does seem to be new to some thoughtless conservationists. Whenever a saving of coal consumption involves a change from a cheap to a more expensive coal there might easily be a financial loss, or when the change involves the abandonment of a cheap coal for an expensive gas or oil there might reasonably be expected a loss. When the change involves the adoption of an engine that cannot be relied upon there will certainly be a loss due to interruption of the service; when the new engine costs more to maintain than the old a saving in coal may not be sufficient to offset the difference in repairs;

when the gas power plant costs very much more than the steam power plant to buy, the interest on the difference between the investments may more than offset a saving in coal. In many ways then it may be true that a saving in coal does not mean a reduction of cost of power, and therefore, does not appeal to the purpose of the purchaser of coal for power. Not until the purchaser of coal for power purposes can be made to see that the use of a gas power plant with its lower fuel consumption than the steam plant will also involve a net gain in the cost of generating power, not until then can the power user be expected to contribute to the cause by using this means of conserving our national fuel supply.

The difference of conditions that produce the different results are chiefly those of size of plant and kind of fuel supply. The gas power plant is not yet completely adapted, although rapidly becoming so, to all kinds of fuel, and many of the most popular kinds of coal, notably of the bituminous sort, are still giving the producer trouble, so that it frequently happens that substitution of gas power for steam power would involve a change from bituminous to anthracite coal or coke, both of which are well adapted to the older form of producer; the time is not far distant when, however, this will not be the case and producers will be available for every fuel. Perhaps the more potent factor is size. The steam power plant is so much more economical of fuel in large sizes than in small, and the gas power plant so constantly economical in all sizes that the difference between them is small in large plants and large in small plants. It would appear on analysis that by reason of certain other conditions, previously mentioned, that in large power plants at the present time burning coal fuel, steam is still cheaper than the gas system, although more wasteful of coal. On the contrary, in small power plants of the size representing the average in use in factories, for example, which is 67 H.P. as reported by the census, the gas power plant is able to save so much coal that it can produce power at very much less total cost than the steam power plant and can give quite as satisfactory service if the proper fuel is available. The cost of producing power in these small gas power plants in the neighborhood of 100 H.P., provided they use the same fuel, will be just about the same and as low as can be done by our largest and best steam central stations of 100,000

H.P. that have taken a great many years to develop. In order that this statement may be more definite I will offer the following figures, recently computed by me for a 75 H.P. plant burning small anthracite coal at $4.00 per ton of 2,000 lbs., a high price, and operating at full load half the time and driving a direct current generator.

SEVENTY FIVE HORSEPOWER PLANT. DIVISION OF POWER COSTS.

	Cost per H.P. hr.	Per cent of total
Fixed charges on investment of engine, producer, electrical generator, switchboard, foundations, building, piping, etc.	.364	28.1
Repairs and maintenance	.046	3.6
Labor	.474	36.7
Miscellaneous	.046	3.6
Coal	.253	20.0
Lubricants	.106	8.0
	1.289	100.00

These figures are based on one of the most expensive types of plants with very liberal labor allowance, so that with less attendance and cheaper machines the total cost would come under one cent during the life of the plant which, of course, would be less than for the better built machines. While it is true that these costs will be affected by changes in any one of a score of items it is quite certain that in small sizes the gas power plant can be shown to be a paying proposition over steam, except where it is to stand idle for much of the time, and where coal is very cheap, such as at the mines, and it is by study of such figures that the substitution of steam can be brought about with consequent fuel conservation. A comprehensive study of every phase of the problem, engineering and economic, scientific and commercial, will lead to the conclusion that as the gas power plant becomes more and more adapted to the various fuels and to the various kinds of service to which engines are put that it will be more than anything else the great fuel supply conservation means, and therefore, entitled to consideration, respect and encouragement by the public in general, and on such grounds that everybody may properly be expected to understand to at least some degree the principles of operation, the application of which is to bring about this nationally important economic result.

The modern gas engine, no matter whether its fuel supply be primarily gas, oil or coal, will involve apparatus whose principal function is to create from the fuel as it exists, an appropriate explosive mixture for use in cylinders. An explosive mixture, such as the gas engine uses, consists of air mixed with gaseous fuel, or with the vapor or mist of liquid fuel, in certain proportions, with which active mixture there will be certain neutral substances like carbonic acid or water vapor. The first essential process in the operation of a gas engine, is then, the making of a mixture of appropriate sort, and this process in turn involves many secondary processes, some of which will be traced. When the mixture is made it must be introduced into a cylinder, and there treated or subjected to certain processes, the first of which is compression. By the movement of a piston the mixture is forced into a small space, the pressure rises and the temperature likewise, and at some high pressure thus developed the fuel intimately mixed with all the air it needs for its combustion and no more, will be ignited by either a hot metal plate or an electric spark. The result of the ignition of this highly compressed and confined explosive charge will be nothing more complicated than a rapid heating of the entire mass as the flame passes through it, and that the flame *will* pass through it is the defining characteristic of explosive mixtures.

Compared with solid gun powder gaseous explosive mixtures, such as are used in engines, are very slow burning, and the rate at which they burn is the rate at which the flame travels through them from particle to particle, technically the rate of propagation. As a consequence of this rapid heating of the confined gases, the pressure very materially rises to perhaps twice what it was before, occasionally 4½ times, rarely 5 times, and the explosive combustion has performed its useful function. The explosive combustion has rapidly caused the pressure of the gases to double, quadruple or more, and in a short time. This high gas pressure acts on the same piston that originally compressed the charge into the confined space, driving it back, and doing ever so much more work than the piston did to it in compression—the difference is the useful work. The burnt gases, when the piston has reached the end of its working stroke, must be expelled, and the whole series of operations making the mixture, introducing it, compressing, exploding, expanding and expelling it will proceed automatically by means of mechanism designed with this end in view.

The gas engine is then primarily a cylinder with a piston and certain means for making proper mixtures, getting them in, treating them right while in and getting the burnt gases out, doing it as often as may be necessary, as fast or slow as may be necessary, and as much as may be necessary. There must also be some element of control, so that if much work is required of the engine much work will be done on the piston by the use of much mixture, while if little work is required by the engine only little mixture will be used. Now, all complicated mechanisms that are seen about gas engines are there for just these things, as well as perhaps a few others, such as lubrication, cooling of the hot walls to prevent them twisting out of shape and to prevent the oil from burning up, but not much more. It is hard to believe that there is not much more than this when studying a large gas engine.

The drawing in of the mixture occupies the whole of the suction or charging stroke. Under the influence of the flywheel the piston returns compressing the mixture with all the valves closed. Near the end of this compression stroke ignition takes place with a resultant pressure rise. This is followed by the expansion of the gases, all valves still remaining closed. Toward the end of this expansion stroke the exhaust valve is open, and the gases begin to rush out. The piston then returns, expelling the rest of the burnt gases or nearly all of them through the exhaust valve which is open: of course some burnt gases

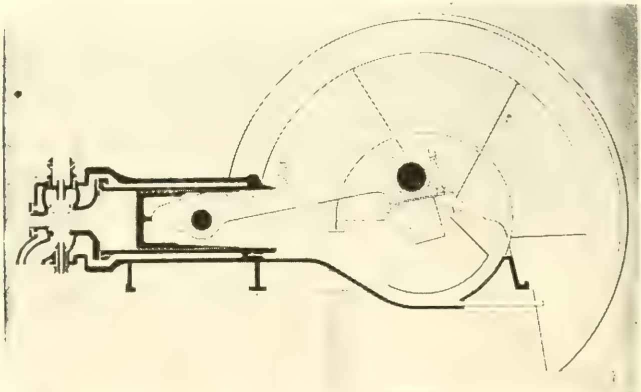

Figure 1.

must be left behind, as much as can fill the explosion chamber. This is the succession of processes occupying four strokes, given the name four-cycle engine.

In structural detail some of the mechanism is shown in Figure 1 for one of these four-cycle engines. Here it appears that the piston has webs under its head to strengthen it. It has rings around part of it, so formed as to prevent the high pressure gases leaking out. There is water all around the cylinder and around the valve chambers. The valves are shown with springs to close them and to keep them closed all the time that some other piece of mechanism is not holding them open, and between the valves is shown the igniter at F, which is nothing more than a device for making an electric spark at the proper time.

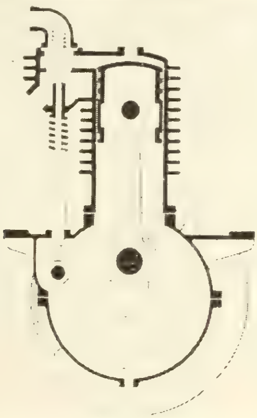

FIGURE 2.

A small vertical engine is shown in Figure 2 in which the two valves are one above the other, the upper one being for inlet, and the lower one for exhaust, both provided with springs to keep them closed, but the bottom one having in line with its stem a push rod against which a cam may act, the cam being only a lump on the small auxiliary half speed shaft. When the cam does strike the push rod it will rise and the valve will open. Both valves might be so operated, and in most large engines are operated by such cams, but in some small engines, such as this, to simplify the engine the inlet valve has no cam to operate it. It is just held to its seat by a light spring. When the pressure in the cylinder due to the suction stroke of the piston, becomes less than atmosphere or less than in the mixture chamber that difference in pressure on the two sides of the valve forces the valve open against the spring. At the end of the suction stroke the difference in pressure is relieved; in fact it would reverse on compression so that the valve promptly closes. The cylinder has no water jacket, but has in its place a number of ribs. The heat from the cylinder will be conducted out along these ribs, and radiated in all directions from them; air blasts are sometimes added to facilitate the coolingof these ribs and the cylinder. This is the characteristic of the air-cooled type of motor which is only useful in small sizes because even the most effective ribs cannot produce good enough cooling for large cylinders, in them water is always used.

Many large engines have two cylinders in which the operations take place on both sides of the piston, making it double acting. The piston in this case is connected to a long piston rod, passing through holes in the heads of the cylinders, these holes being packed by stuffing boxes to prevent the leakage of gas, just as the piston is packed to prevent the leakage of gas. Such piston rods and pistons would get red hot in a short time, and twist out of shape if not cooled, so the pistons and rod are made hollow, and water is circulated through them just as water is circulated around the cylinders and valve chambers.

A group of seventeen large engines, were installed in the Gary plant of the Indiana Steel Co., each of over 3,000 H.P. All of these engines are four-cycle engines, that is to say, for every stroke used in drawing in a charge three other complete strokes are necessary, one to compress, one to expand and one to exhaust, so that with such large double acting tandem engines there is an explosion in each chamber each fourth stroke so that with the four chambers each stroke of the piston rod is a working stroke, and for a twin engine there will be two impulses forward and two impulses back or four total impulses for each revolution of the flywheel.

Engines are made to operate under another cycle so far as the cylinder functions are concerned. For example, Figure 3 indicates an engine that does not have as many valves as the others we have examined but it has something in place of them. It is a two-cycle engine, so called because it can carry out all the necessary series of cylinder operations in two strokes instead of four. This is done by utilizing the other end of the cylinder, which in a single acting four-cycle engine is idle, or what is the same thing, by utilizing a closed crank case, or what is likewise equivalent in very large engines by adding pumps, one for air and one for gas. The function of these pumps or the crank case, or the forward end of the cylinder if closed, is to get ready the mixture so that it can be puffed into the cylinder during a portion of the stroke without using up a whole stroke. Referring to the figure it will appear that the piston is fitted with a lip G which in the position shown is just underneath a slot in the cylinder marked I, communicating with the passage B, C, D, to the forward end of the cylinder and communicating likewise at the bottom of B with an inlet valve A. This inlet valve is of the automatic sort having no cams to open it. Just at the bottom of the cylinder there is another slot connecting with the exhaust pipe marked E. Imagine the piston to move to the left, then whatever is in the cylinder when the piston covers the slots or ports, I and E, will be compressed. At the same time there will be a suction in the chamber B and C and lifting the valve A, allowing mixture to follow in behind the piston in the chamber D while the compression is going on to the left. When this compression is all over, the igniter, placed at F, will fire the charge, the piston will move to the right expanding the hot gases on the left hand side and compressing the mixture on the right hand side in D, C, B.

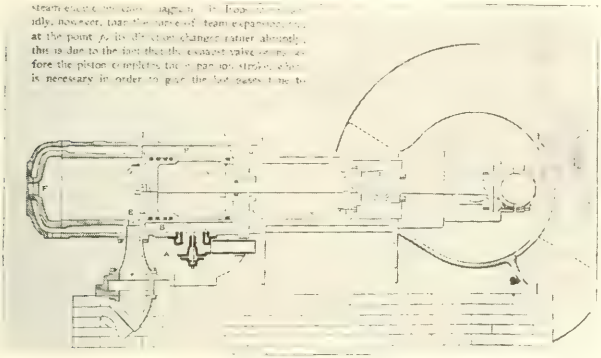

Figure 3.

When the piston has reached the point of uncovering E, the high pressure hot gases will rush out through the exhaust pipe, as indicated by the arrow. In another moment the top of the piston will have uncovered the port I, communicating with the fresh mixture in B, which will rush in because it is compressed and the pressure in the cylinder is now low, having been relieved through E, but in rushing in the mixture will be deflected by G, the lip on the piston, and will so rush down to the end of the cylinder and be reflected back toward E, pushing out in this way much of the burnt gases that may be left. Thus exhaust is accomplished and a new charge fed in during the time it takes for the piston to uncover the port E and get back again so as to cover it up. This series of operation is accomplished in two strokes and gives the two-cycle engine its name.

All modern gas engines subject the mixture after it goes to the cylinder to essentially the same series of processes, however much they may differ in other ways structurally. The principal differences are to be found in the means for making mixtures and adjusting the quantities and preparing natural fuels, vaporizing liquids and gasifying coal. The first and most vital function of a gas engine or its auxiliary parts is to make proper explosive mixtures. This is often lost sight of even by designers in their efforts to produce a strong, durable and pleasing structure, cheap enough to sell. It is, however, the most important thing to study today, as a process and one lacking complete scientific data for its proper understanding.

Chemically speaking, a mixture is proper when it contains exactly the amount of oxygen necessary to burn the fuel, no more and no less, and when at the same time by reason of perfect mingling, each particle of fuel is in direct contact with its own share of oxygen. Since we must draw our oxygen from the atmosphere, such mixtures cannot be obtained because each particle of oxygen would carry with it, roughly, five times its own amount in nitrogen, which is neutral. When a mixture contains, therefore, fuel and air with perhaps other neutrals, and when the oxygen and fuel portions of the mixture are in the right proportions the mixture is explosive. It is explosive in the sense previously described: that a flame once started will travel through the entire mass. If then at a point in such a mixture the temperature be raised high enough to start combustion, that is to say, to the temperature of ignition, combustion will be communicated with approximately equal rapidity to each adjacent particle in all directions. In a short time there will be truly a ball of fire inasmuch as the flame will lie in a thin layer all over the surface of a sphere, the interior of the sphere being filled with hot burnt gases and outside of the sphere mixture as yet unburned. At each succeeding moment, although the velocity of propagation may be just the same as before, a greater and greater volume of mixture will be burned as the surface of the sphere gets bigger and bigger. It appears then that this sort of combustion may be properly termed spherical in character and it accelerates itself in so far as the volume of mixture burned per second becomes greater and greater as the radius of the sphere on which the combustion is proceeding grows bigger.

The regular acceleration of the rate of combustion is of vast importance in engines, but the uniform flame propagation with which it is associated does not maintain for long. There is an even greater tendency to accelerate, due to the elastic nature of gases. It is plain that with the first little burst of flame a sort of pressure impulse or wave will be transmitted through the mass. It is found in actual observations on mixtures that while at first the flame movement seems to be uniform it shortly becomes oscillatory. This may be due to the fact that in mixtures of high pressure flame travels faster, so that at the crest of the little wave started from the first burst of flame there will be momentary an acceleration of combustion followed by a retardation as the crest changes into a hollow and then the hollow becoming a crest again, giving an alternately slow and fast flame movement which in time will meet a returning wave, a wave that has been sent to the limits of the chamber and reflected back. It seems at times as if such reflected waves and progressing waves superimposed their crests, producing localized spots of very high pressure and very fast combustion. Such localized fast combustion is detonating in character, and designated as the explosive or detonating wave. Students of explosive mixtures recognize not only the uniform movement with which combustion seems to start, but also the oscillatory movement of the flame which follows it, and later that most interesting phenomenon, the explosive or detonating wave. So far as the engine is concerned these facts are interesting in two ways ; first, with regard to the continually accelerating rate of combustion, and second with regard to the momentary high pressures that come and go, apparently without reason, simply because we have not yet discovered the reason, but imagine it to be some such synchronization, as I have described.

The addition of much neutral to a mixture will cause the whole combustion to proceed much more slowly, and in fact a mixture with a very great amount of neutral can be no longer burned, so that it appears that much neutral may render an otherwise explosive mixture non-explosive and useless.

It is possible to overcome this tendency in weak mixtures, for it is found that a mixture so weak that it will not burn in the open air will, if compressed enough, burn quite readily, so that a mixture that contains the limiting amount of neutral for explosive combustion and is, therefore, non-explosive, becomes explosive if it is previously compressed. This makes it possible to run engines with mixtures so weak that they would not burn in the air dull with fuel gas so weak that it would be otherwise quite useless.

It would seem that if there were too much air for the fuel that it might be treated as a neutral because it is inactive, and this is correct. It may be so treated. As a consequence it appears that mixtures with more air than is chemically needed are explosive as well as those chemically correct upon to within a certain limit of course. On the other hand mixtures that contain more gas than the air present can burn are likewise explosive up to another limit, the extra gas behaving as neutral because it is inactive. Mixtures, then, may be explosive through quite a wide range of proportions of air to fuel or quite a wide range of proportions of active and inactive diluent materials. The range of proportions of explosive mixtures is greater the richer the original fuel. Thus for kerosene, gasoline, natural gas and similar rich substances the range of proportions of air to fuel is very great, while with blast furnace gas, a very weak gas, the range is not so great. In every case, however, the range of explosive proportions becomes wider and wider the more they are compressed.

The piston speed of the engine is zero every time the piston is at the end of the stroke ; it rises to a maximum somewhere about mid-stroke and falls again to zero. It is found in practice, and it can be thermodynamically demonstrated that it ought to be the case, that we get the best results when the combustion is completed as nearly as possible before the piston begins its outward movement. It would seem from this that combustion should be completed between the time when compression is completed and when expansion should begin; that is to say, it would seem as if the explosion should be completed in zero time.

Now, as a matter of fact the conditions are not quite so severe, and it is found by igniting the charge a little before compression is finished that the flame acceleration, which is natural to the mixture, will be in most cases quite enough to practically complete the combustion before the expansion stroke begins. If ignition were delayed much the piston speed would have increased so much that in a certain sense the combustion would never catch up with it, and instead of getting high explosion pressures at the beginning we would have low ones; instead of getting most work from the heat by expanding after combustion, we will get a less amount of work, because expansion would be proceeding during combustion. The time of ignition, therefore, must be carefully adjusted, first with respect to the piston speed, and second, with respect to the natural rate of combustion of the mixture. A mixture which is too slow burning for a given piston speed may be accelerated by increase of compression, and to a certain extent this adjustment can be made. There is, however, another limit imposed. The limit is imposed by the natural temperature of ignition of the mixture. As the mixture is more and more compressed, so does it become hotter throughout its entire mass, and somewhere, sometime it will get hot enough to ignite itself, independent of the spark. This is called self-ignition or pre-ignition. It is found in actual work that while a weak gas mixture can be made faster burning by compression, it cannot be made as fast burning as a rich gas mixture, because the compression cannot be carried far enough. It ignites itself before as much compression as might be desired, has been attained. It might seem from these arguments that it was desirable to highly compress weak mixtures only to make them burn fast enough, but as a matter of fact it is desirable that we should compress all mixtures as much as possible. One of the principal propositions concerning engines of this class that it is the province of thermodynamics to solve is the fact that the more the compression the higher the efficiency, and without limit. An engine, then, using a mixture that permits of high compression, whether it may be rich or poor, should by reason of that high compression alone, give a high efficiency and, within certain limits, this is found to be true in practice. It is also found that our desire for high compressions and high efficiency is limited only by the temperature of ignition for the mixture, and in general, though not always, the richer mixture will stand the least compression. More particularly is it true that certain hydrocarbon fuels, such as kerosene, gasoline, will stand the least compression before ignition, and likewise mixtures with hydrogen will stand less than mixtures without hydrogen, other things being equal. The limit of compression, then, is set in practice by the temperature of ignition, and this in turn depends upon the nature of the fuel, so that with different fuels we do not get quite the same efficiency, although thermodynamically we should if this physical property of the fuel could be avoided, and it is in some less common engine forms.

In general, it happens that the weaker gas mixtures will stand the higher compression, although natural gas, which is rich, will stand almost as much compression as the weakest of all the fuels, blast furnace gas. This is a curious fact, and is the cause of the first suspicion that richness of fuel is not necessarily a measure of its temperature of ignition. Studying the temperatures of ignition of various mixtures it was found first, that richness of the fuel had nothing to do with it as such, but that the ignition temperature depended on the chemical nature of the fuel. Studying the subject still further it was found that the temperature of ignition did not depend upon the chemical nature of the fuel alone. It was, therefore, not right to say that gas that contained hydrogen, for example, would ignite at a lower temperature than a gas that contained carbon monoxide, CO, even when it was known that hydrogen itself with oxygen ignited at lower temperatures than carbon monoxide alone with oxygen. At the present time it is quite generally understood that the temperature of ignition is a function not only of the chemical nature of the fuel, but of the other elements of the mixture with which it is associated, and the relative amounts of all things present. The prediction of the temperature of ignition for any complicated engine mixture is, however, still quite impossible, so that limiting compressions and efficiencies can only be found by trial. There is room here for some valuable pure science contribution to the development of this problem.

So far as the engines themselves are concerned these principles of explosive mixtures are valuable in two ways. First, in dictating how they may be treated, and second, in explaining things which happen but which were not foreseen, and a knowledge of such mixtures is quite essential to a scientific understanding of the gas engine. We are, however, concerned principally with one part of the application of this subject. The engine will run properly and best when its mixture is most constant, when the engine gets the proper quantity of this mixture and when the mixture received is compressed as highly as possible without carrying it beyond control. As previously stated, by far the greatest variation in the mechanism of engines, and by far the greatest complication in their mechanism, is found in that part of the valve gear which is concerned with the proportioning of mixtures, the actual mingling of the parts of the mixture and with the adjustment of the quantity in proportion to the work to be done.

Mixtures are proportioned in engines as they are drawn in. In other words they are proportioned as they are made. The suction stroke of the piston starts a movement of gases toward the cylinder, and as there will be two sources from which to satisfy this displacement, one the atmospheric air and the other the fuel gas chamber, it is plain that if a valve in the fuel gas pipe be closed and the air opening free nothing but air will enter, or if the air valve be closed and the gas valve opened nothing but gas will enter, so if a valve be opened in both the air and the gas ports, both air and gas will enter and the proportions will depend upon the relative openings. This is the primary principle of proportioning used, openings for air and gas, means for adjusting those openings so that the relative amount of air and gas can be adjusted. These valves for adjusting the proportions are generally independent of the valve controlling the mixture admission to the cylinder and may together or in conjunction with some other device be called the mixing valves or proportioning valves of the engine. In Figure 4 is shown an inlet valve, gas and air ports, each with damper valves in them, the gas pipe being the upper one. On the suction stroke of the engine the slide attached to the valve stem will be drawn down, the clots will register, and the gas drawn past its damper will pass through the ports to the air chamber meeting air from the other pipe and the mixture will enter the cylinder. The slide is added to the inlet valve to prevent the gas, which is generally under some pressure, flowing into the air passage when the piston suction ceases. If this were omitted there would be a tendency for the mixture to become too rich at low loads or at intervals between suctions. This slide, therefore, serves to overcome this tendency of the gas to catch up on the air by reason of different pressures.

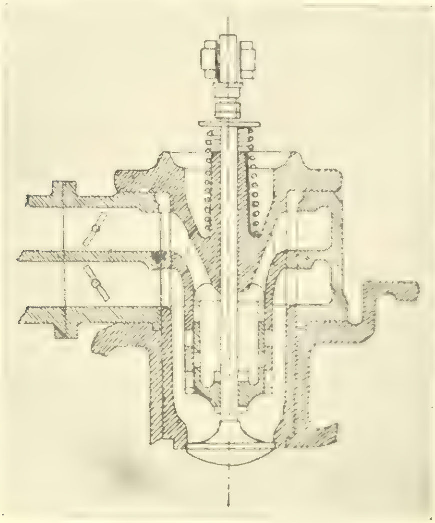

Figure 4.

As the atmospheric air has no tendency to flow except during suction, the air damper valve might be done away with and in many engines actually does not exist.

Similarly, the slide attached to the valve stem to prevent the gas catching up to the air is often omitted and other things substituted in its place.

Some mixing valves are connected with the main inlet valve, but in some of our best engines they are independent, quite separate pieces of mechanism, their only function being to proportion mixtures and maintain the proportions while the main inlet valve admits the mixtures thus made in quantities desired. Thus Figure 5 shows air and gas valves leading from separate chambers, one for air and one for gas, and both discharging into a mixture chamber communicating with the main inlet valve. This is a good example of an independent mixing valve in which the air and gas openings are operated mechanically with cams and links, which can be adjusted by the governor to vary the amount of opening of both air and gas valves but in proportion, no matter what the total quantity that passes.

It is possible and in fact it seems even desirable that the mixing valve be operated independent of the main inlet valve, independent of the quantity control valve and automatically instead of mechanically. The relative advantages of all these ways of making mixtures and proportioning them, together with perhaps hundreds of other different ones in use, are, of course, beyond the province of such a lecture as this. I show these solely because these functions of mixing and proportioning and controlling quantities are important enough to receive separate and detailed study on the part of designers, and it is a fact that the success of gas engines depends very largely upon the success with which these details are worked out.

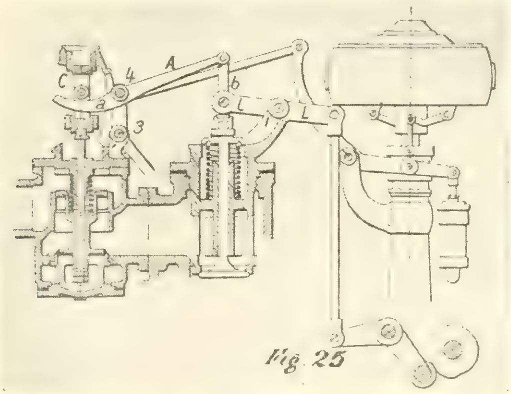

FIGURE 5.

When the mixture is made by means, such as we have examined, the next thing necessary is to adjust the quantity that the engine may receive, which may be done by a damper valve between the mixing valve and the main inlet valve. This is one of the simplest and most effective means of controlling the quantity of mixture. The main inlet valve opens the same amount every time, but the amount of mixture that the engine gets will be zero if this damper is shut, and a maximum if it is opened. The amount of this opening is, therefore, a measure of the quantity of mixture the engine can get, while the mixing valve makes automatically whatever is required, preventing at the same time the passage of gas into the air pipe or the passage of air into the gas pipe, and proper stirring means provided to bring the two parts of the mixture intimately together. It is the function of the governor of the engine to fix the position of this damper. At light loads the speed rises, and certain free weights of the governor move the damper to the closed position, at heavy loads to the shut position and such sensitiveness can be secured as is surprising to a stranger. An engine can by such means as this be kept at speeds between 148 R.P.M. and 152 R.P.M. just by moving that damper, which means that the damper is wide open when the speed is 148, and that it is practically shut at 152, and it moves from wide open to shut in these 4 R.P.M., all entirely automatically. This device is an example of the principle of controlling the quantity of mixture by a valve, independent at the same time of the mixing valve and of the main inlet valve. There are other ways of doing the same thing, and many of them.

I think, however, from what I have said that you will have a fair idea of the problem of making the mixtures with gas when the gas is in available form, and of controlling the quantity that the engine is to receive, proportioning it to the work to be done.

The next step will be to examine the preparation of the fuel before the mixing valve and main inlet valve are permitted to get it, as most of the fuel available is coal and oil, the only available gases in the gaseous state being limited to blast furnace, natural gas, coke-oven gas and city illuminating gas, all of which are of minor general importance compared with coal and oil.

By far the biggest problem before us is the preparation of solid fuel, and the apparatus by which this is done is technically called a producer, though actually consisting of a producer for making gas and means for cleaning the gas made. The gas producer is a piece of thermo-chemical apparatus essentially very simple, and in view of the great simplicity of its action it is somewhat surprising that its actual adaptation to commercial power conditions has taken so long a time. A producer consists essentially of nothing more than a thick bed of fuel in which it is supposed that two sorts of reactions take place: one the burning of the fuel with air, making carbon dioxide or CO_2 gas, just as happens in every steam boiler or household furnace; secondly, the passing of this hot CO_2 gas with, of course, nitrogen which the air carries and which is neutral through some more hot solid carbon. This solid carbon unites with the gaseous CO_2, each particle of CO_2 taking another particle of C, making 2C and 2O in combination, or two particles of CO gas, which is carbon monoxide. A simple elementary producer then would consist of nothing more than a thick bed of coal or coke from 2 to 4 feet thick, and would yield a gas consisting of about 30 per cent CO and 70 per cent of nitrogen. This would be the elementary producer gas which is quite like blast furnace gas and very valuable for engine service. This simple action would, however, be impossible in practice, because all coals and a good many cokes contain some volatile matter, material of the gaseous or tarry form which is driven off under high temperature, and which would mingle with the CO and the nitrogen which are generally classed under the heading of volatiles, and some coals contain as high as 50 per cent by weight of such volatile matter. In addition to this volatile another element will be introduced and must be introduced in most gases, and that is hydrogen. The continuous operation of this elementary producer just described would make it hotter and hotter, and in a short time would fuse the ash, making a clinker or slag and choking up the fuel bed. To prevent such fusion of ash the common and standard practice is to introduce water vapor, which is decomposed in the hot zone, chilling the ash which is about to fuse by robbing it of the heat for the dissociation. As a consequence of this dissociation there will be added to the producer at that point oxygen and hydrogen, the oxygen behaving with the rest of the fuel just the same as the oxygen from the air, while the hydrogen will pass through unchanged. By reason of a poorly compacted fuel bed, either at the top or bottom, there will be some small quantities of free oxygen and some small quantities of CO_2, so that a producer gas from a common coal would consist first of CO, second of hydrogen, third of certain volatiles, fourth of a little CO_2, fifth of some oxygen, and finally, but largest of all quantitatively, nitrogen. This is producer gas, and this is the result of passing air and steam through a thick fuel bed supplied with coal, but gas thus produced is dirty. It contains two kinds of dirt. First, solid dust, and second, the vapor of sticky tar, which on cooling condenses and interferes with the operation of the engine.

There are a great many schemes available for removing dirt more or less completely, most of them quite simple in conception, as for instance an ordinary spray tower, the gas passing upward through wet coke, while water sprayed from the top runs downward to keep the coke wet. The primary object of this sort of cleaning tower is to catch dust, and this it does pretty well. It also, however, cools the gas, and so causes a certain amount of tar to condense, though not enough to render it efficient as a tar extractor. Other forms of tower involve all sorts of systems for extending to the gas a great number of square feet of wet surface, and all cleaners of this sort may be called static cleaners of the contact sort. Another type of cleaner is the filter sort. In this the gas is forced through spaces between finely divided material, such as sawdust, excelsior, wood chips, in which fibrous or filtered materials rest on pans, arranged for convenient removal when dirty. A third class of cleaner, which has

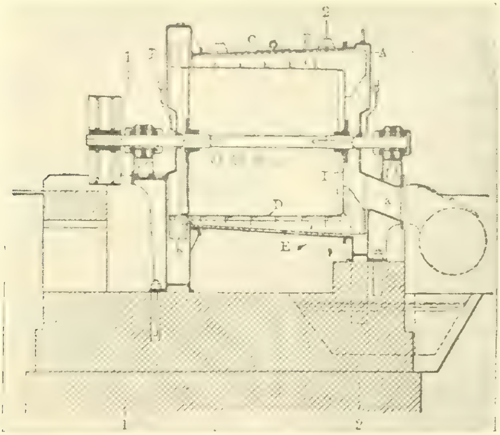

Figure 6.

proved more effective for tarry substances, but which is also effective for dust, is of the rotary sort. In it, rotating masses, dipping into water, throw a continuous spray across the chamber through which the gas must pass. Such a cleaner is shown in Figure 6. The ribs on the drum D catch water in the bottom of the casing, throw it out by centrifugal force, the gas meanwhile passing through the veils of mist at right angles. It is quite beyond the scope of this paper to go into all the different kinds of cleaners and discuss their effectiveness. My object in showing a few is merely to indicate that gas cleaning is a very important part of the preparation of coal made gas for engine use, and unless mixture is made from clean gas the engine will suffer.

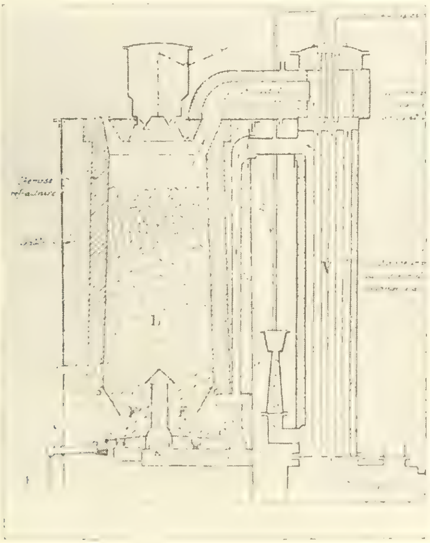

FIGURE 7.

Returning now to the producer itself, Figure 7 indicates one form of up-draft producer. Through the coal bed L, air and steam are blown up through the center pipe K, which projects through the grate G and through a mass of ash F, left on the grate. The passage of the air and steam through the coal bed produces the gas, which issues at a temperature somewhere near 1,000 degrees Fahrenheit. This hot gas impinges on tubes which superheat the steam on its way to the blower, which is of the injector sort, and which is shown in the bottom center of the cut. A jet of steam entering this blower draws in air and the mixed air and steam pass up around the tubes of the heat exchanger B, being heated thereby by the hot gas on its way to the scrubber. In this way not only is the air steam mixture supplied to the feed pipe K, but it is supplied in a highly heated state and under pressure enough to force the gas that is made through the entire system to the engine. Such producers are termed "pressure producers," because the gas is under pressure and the ash pit is under pressure and must be kept closed, and they require either a steam jet blast like this or a fan blast. In any case high-pressure steam is necessary to operate the blast so that a small steam boiler will be required as an auxiliary.

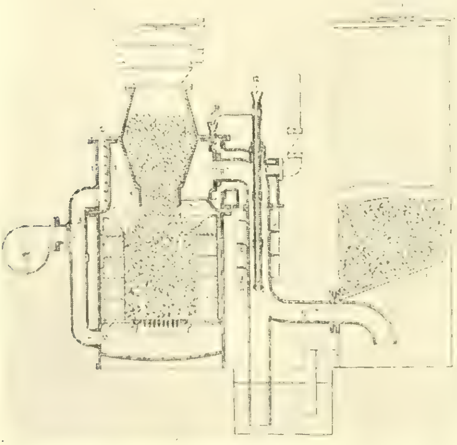

Figure 8.

A producer operated without pressure in its chamber, but rather at a slight vacuum, is shown in Figure 8, the vacuum being maintained by a fan or blower between the scrubber and the engine or by the suction stroke of the engine itself. This combination makes the suction producer, and when the suction is produced by the engine itself it appears that the suction stroke of the engine not only makes the explosive mixture at the inlet to the engine cylinder, as explained, but also draws air and steam through the fuel bed of the producer to make gas as required. To make the steam for such a suction producer no boiler is used, but on the contrary the sensible heat of the hot gases leaving the producer is sufficient. In this particular case water fed down through the tube at 2, which dips into the hot gas pipe, will overflow into the funnel, partly warm. From the funnel it will run down an incline of narrow shelves or ribs around the upper chamber of the producer, as indicated at 1, becoming vaporized. Air drawn in at 4 becomes warm from the ribs 5 on the gas pipe and becomes still warmer from the ribs 1 on the vaporizing tube, at the same time picking up the water vapor there formed. The mixture of water vapor and air passes downward to the ash pit 10, then upward through the fuel bed, gasifying the coal and finally out through the scrubber to the engine.

Some little difficulty occasionally arises in these producers from clinkers due to insufficient steam or a poor grade of coal; occasionally an excessive amount of steam will give the gas too much hydrogen and occasionally the proportions of air and steam supplied may vary, causing the gas to vary in composition chiefly through changes in the ratio of hydrogen to carbon monoxide. With proper fuel and decent care, however, producers of this sort are quite reliable and in fact less likely to give trouble than a steam boiler. Fuel is proper for these producers when it is hard, having little or no tar and of sizes which will not pack too tightly, as a tightly packed bed is difficult for the air to pass through.

When, however, it is desired to operate with bituminous coal, which contains much tar and which has a tendency to melt like molasses candy in hot weather immediately when heated, producers of the sort just shown are no longer satisfactory. It is not sufficient to merely attach to them tar extractors no matter how perfect they may be as extractors, because the primary trouble is in the fire which requires too much attention to maintain it in proper condition against caking and which has a tendency to make variable and tarry gas, or in place of the tar, soot or lampblack, variable because of the unequal rate with which gas distils off. Various plans have been tried and others are being proposed every day: some of them are in the experimental stage, others no more than proposals for overcoming the caking tar and fluctuating volatile difficulties of the rich, bituminous coals. One principle involves the reversal of the draft so that coal fed to the top would be supplied with air at the same place and would pass downward through the bed instead of upward. The passage of the volatile of the coal downward through the bed is expected to decompose the unstable tarry hydrocarbons to stable gases and fixed carbon soot that would not give trouble, and this is more or less effective. A good deal of difficulty, however, also results from this decomposition, and the soot is almost as troublesome as the tar itself.

The latest thought seems to be mostly directed toward another plan which would involve the elimination of all the tar and all the rich volatile of the coal, and would produce a very poor gas but a steady one. Figure 9 indicates one form of producer embodying this idea. There are practically two fuel beds, although they here join and air can pass through a common sort of grate at F, burning the coal just as it burns under a boiler. As the coal passes down and across grate F all the sticky, tarry substances will be driven off and fill the upper chamber with a long flame. At the bottom of the grate there will be left of the original coal nothing but coke through which in the lower chamber the more or less completely burned volatile and tar will pass and be reduced to

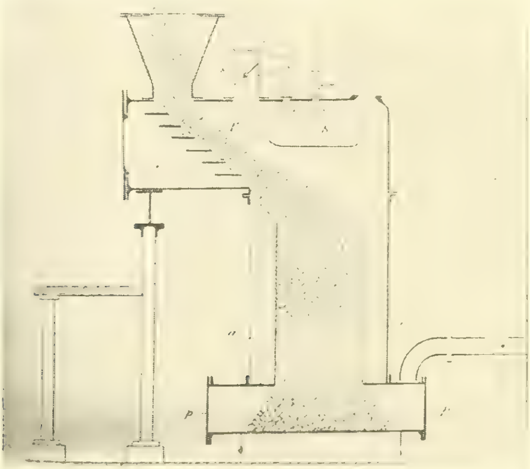

FIGURE 9.

combustible CO and hydrogen. This arrangement would have been improved by making the top grate of the movable sort to prevent the coal caking as it distilled and likewise would have been improved by a separation of the two fuel beds quite completely, so that no unburned volatile substances or tar could possibly reach the lower fuel bed. That there are real difficulties with the handling of bituminous coals and for special grades of coal, including everything down to peat, was not originally recognized, but is now completely recognized and great progress is being made, so that while it is true producers of this sort can hardly be considered to have reached a commercial stage, they are coming and will soon be available, and when they are the gas power plant will become a universal competitor of the steam power plant so far as the fuel supply is concerned.

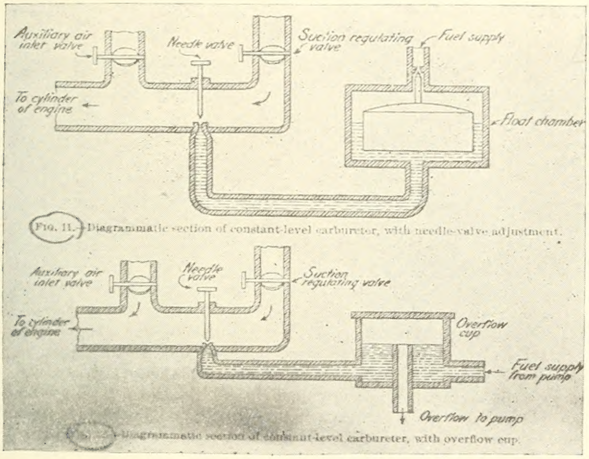
Auxiliary air inlet valve
Needle valve
Suction regulating valve
Fuel supply
To cylinder of engine
Float chamber
Fig. 11.—Diagrammatic section of constant-level carbureter, with needle-valve adjustment.
Auxiliary air inlet valve
Needle valve
Suction regulating valve
To cylinder of engine
Overflow cup
Fuel supply from pump
Overflow to pump
Diagrammatic section of constant-level carbureter, with overflow cup.

FIGURE 10.

With regard to liquid fuels: there are two modes of operating in the preparation of the mixture; one, very direct, is applicable only to the more volatile fuels; the other, indirect, to the heavy and less volatile. The more volatile forms of fuels are treated by devices which perform a variety of functions at once. They automatically feed the fuel to the vaporizer, which mixes it with air and maintains the proportions. Thus, in Figure 10, if we imagine gasoline fed into a float chamber through a valve controlled by the float, the supply will be shut off when the float in the chamber reaches a certain height. If now, there be a nozzle connected with the gasoline from the float chamber, the end of the nozzle just a little above the level in the float chamber, and a needle valve in the nozzle to adjust the effective opening, no gasoline will flow out except when the movement of the piston creates a suction at the nozzle, and the amount that will flow under suction will depend on the amount of suction and needle valve adjustment. To facilitate adjustment of the suction a valve may be provided in the air pipe, as shown at the right, and proportions between the liquid gasoline and the vapor maintained by the needle valve and the air valve, just about the same as was done with the mixing valves for the gas engines previously described. There is an element of interference, however, because we are attempting to control automatically the proportions between a liquid on the one hand and a gas on the other. It is found by experience that there is a tendency for the gasoline flow to increase faster than the air, and for that reason an auxiliary air valve is often provided, either hand adjusted or automatic. Such a combination of parts constitutes a carbureter. Vaporizing in it is quite automatic, as the air is hot enough to vaporize the gasoline spray by contact alone, or vaporize enough of it to permit the cylinder to complete the process in compression. I could show you, perhaps, 300 different combinations of mechanisms, all constituting

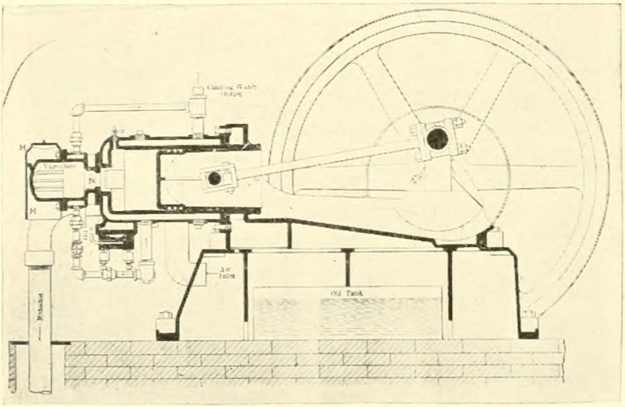

Figure 11.

carbureters, but the adopted principle is just as well shown by this diagram.

Another mode of vaporizing liquid fuel involves the use of a vaporizer, distinguished from a carbureter by the fact that it does no mixing, and is employed generally for heavier oils, which require high temperatures to convert them into the vapor form. These vaporizers may be independent of the engine, being in effect independent gasifiers, or may be, and more often are, integral parts of the engine itself, such as shown in Figure 11, where an ordinary four-cycle engine, ordinary in all respects except this, has in place of the regular head a bulb chamber connected to the cylinder by a neck. This bulb chamber, at its outer end, gets red hot, and in the beginning is heated by a lamp placed under it. Heavy oil, even as thick as cold molasses, when pumped into this chamber will vaporize; the compression stroke of the piston will force air into the chamber, and passing the neck the air will whirl around inside the bulb, mixing with the vapor, and ultimately, as the compression is carried on, so heating the mixed vapor and air as to cause an automatic or self-ignition.

I have shown you the ordinary means of altering natural liquid and solid fuels into available form for the making of explosive mixtures, the ordinary means for proportioning the air and fuel in these mixtures, and for controlling the amount of mixture, typical forms of mechanisms for using such mixtures—all of which constitute the essential processes in the operation of the gas power plant. I have shown you quite a variety of some of these pieces of mechanism for the purpose of indicating that progress toward perfection is being made, and that while much is yet to be done, it certainly will be done, and the sooner, in proportion as our best engineers are induced to turn their attention toward the problem. I can safely predict that the gas power plant will yield results in a reasonable time that will so perfect it as to make the gas power plant actually, what it has long promised to be, the great factor in power fuel economy, and the greatest of all possible practical and common sense means for the conservation of the national fuel supply.